

THE INFLUENCE OF WEATHER IN HEAT PUMP SYSTEMS

Clito F. Afonso^{1,2(*)}

¹INEGI, University of Porto, Porto, Portugal

²Department of Mechanical Engineering (DEMEC), University of Porto, Portugal

(*)Email: clito@fe.up.pt

ABSTRACT

The aim of this work is analyze the influence of the weather in the operation and behavior of heat pumps. They are similar, the difference between them being the evaporator. One operates, with an evaporation temperature 9° C below the ambient temperature (system 1) and the other one (system 2) with a constant evaporation temperature equal to 0°C wherever possible. The purpose of the heat pumps was for heating a small office. For both systems a constant temperature of 20°C was set to be kept in the office. The working fluid is the R134. In order to analyze the influence of the ambient temperature upon the energy consumption of the heat pumps, three different cities were chosen: Porto, Bragança and Faro located in Portugal. The study was carried out monthly for one typical year of these cities. With these results it was concluded that the design of a heat pump depends on the local weather as well as the time of the year in which it operates, the energy consumption being higher in months with lower temperatures. It was also possible to conclude that the work expended by fans, necessary to increase the coefficient of heat transfer in the heat exchanger of the system, can be decisive in the economy of the energy consumption. These reasons lead to system 2 which is more efficient in locations with mild climate and system 1 better in colder climates.

Keywords: heat pumps, evaporators, COP, energy consumption.

INTRODUCTION

Currently, the use of refrigeration systems is indispensable (Afonso, 2012). They play a fundamental role in areas ranging from the preservation of perishable products, the pharmaceutical industry or air conditioning. In fact, uncommon is the house where there are no refrigeration systems installed, be it air conditioner or the refrigerator itself. The scale of applications increases significantly when, instead of considering only domestic applications, it is taken in account industrial, commercial, transportation, among others.

In recent years, with the concept of sustainable development (Bulletin of IIR, 2002), it became clear that changes would have to be made to conventional refrigeration systems trying to increase their efficiency to the maximum, and so, reducing the energy consumed without compromising the heating effect.

Besides the compressors, the major energy consumer of these systems, the evaporators also influence the energy consumption, due to their design as well as its dependence regarding the weather.

In this work the simulations were carried out using the Pack Calculation Pro software (IPU, 2016).

THE SYSTEM and COMPONENTS

The system of the heat pumps is shown schematically in Fig.1, with two compressors working in parallel and with an internal heat exchanger. Both systems are a single stage compression and expansion.

The compressors chosen have the characteristics represented in Fig.2.

The two compressors chosen are identical, Bitzer model 2CC-6.2Y, and they can operate between an evaporation and condensation temperature of -15°C and 22°C respectively. The cooling power is 20.5 kW and the heating power is 25.7 kW when the outside temperature is -12°C .

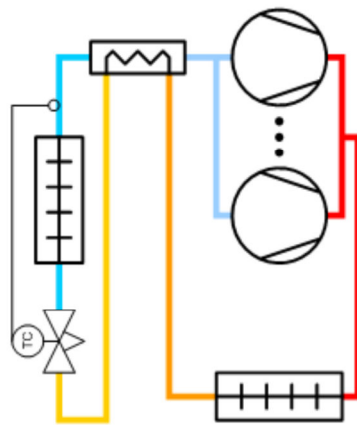


Fig. 1 - The heat pump studied.

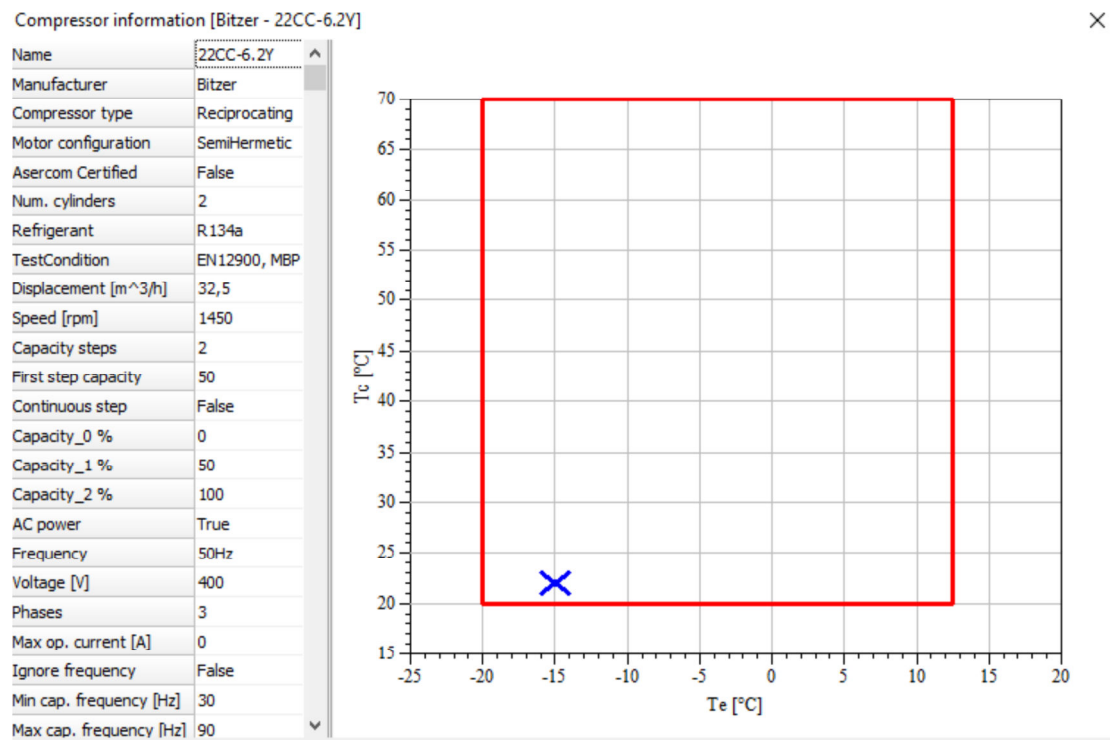


Fig. 2 - Characteristics of the compressors.

For different outside temperatures, the necessary heat power is:

$$Q_c = 25,7 - 0,04 \cdot [T_{\text{out}} - (-12)] \cdot 25,7 \text{ [kW]}$$

In order to know from which ambient temperature there is no heating, it's enough to equate the equation shown to zero and obtain a temperature of 13°C. That is, whenever the ambient temperature is equal to or greater than 13°C, the system shuts off and there is no heating power.

As said, system 1 imposes an evaporation temperature dependent on ambient temperature. The evaporation temperature, T_e , is always 9°C lower than the ambient temperature. In addition, the maximum evaporation temperature was fixed at 8°C, the overheating temperature considered was 10°C totally useful. Finally, it was considered that the heat source with which the evaporator exchanges heat is air, the efficiency of the internal heat exchanger is 40% and the fan speed, used to increase the coefficient of heat transfer, is controlled.

RESULTS

Porto city

Fig. 3 displays the monthly energy consumption of both systems for Porto city.

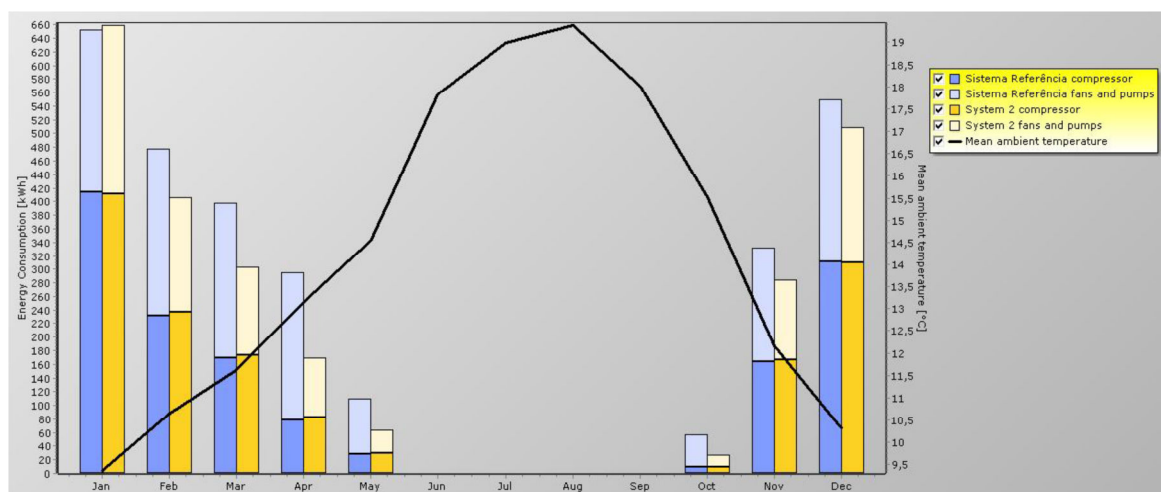


Fig. 3 - Monthly energy consumptions for the two heat pumps in Porto city.

In the dark and light blue bars it is represented the energy consumed by the compressor in system 1 and the energy consumed by pumps and fans 1. Similarly, the bars in dark orange and light shows the same kind of information, but in relation to the system 2. The black curve represents the outdoor average temperature along the year. It is possible to observe that January represents the month of greatest total energy consumption, 651.8 kWh for system 1 and 658.9 kWh for system 2, and in June, July, August and September the two systems do not operate completely.

Table 1 represents the summary for one-year operation. In the results of this simulation it is emphasized that in both cases 100% of the load was always satisfied and therefore the systems would have no problem to meet the requirements. Another point to note is that for the weather conditions in Oporto, system 2 performs better with a COP of 4.1 against a COP of

3.46 of system 1, which would represent an annual saving of 449 kWh of energy or 16 % Of the total energy consumed by the system 1.

Table 1 - Behaviour of the heat pumps in Oporto city.

	Sistema Referência (reference)	System 2
Load fulfillment		
% of time:	100,0	100,0
% of energy:	100,0	100,0
COP		
Average COP [-]:	3,46	4,10
Energy consumption		
Pumps and fans [kWh]:	1 464	1 001
Compressor [kWh]:	1 405	1 419
Total [kWh]:	2 869	2 420
Savings		
Yearly energy savings [kWh]:	-	449
Yearly energy savings [%]:	-	15,6

Bragança city

Fig. 4 displays the monthly energy consumption of both systems for Bragança city. As for Porto city, the meaning of bars is already explained.

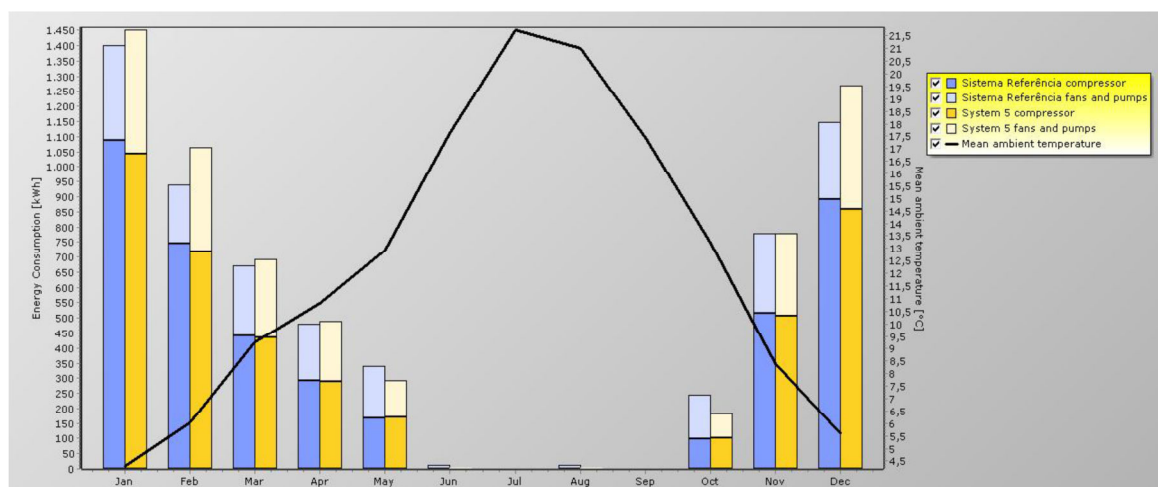


Fig. 4 - Monthly energy consumptions for the two heat pumps in Bragança city.

Table 2 represents the summary for one-year operation.

Table 2 - Behaviour of the heat pumps in Bragança city.

	Sistema Referência (reference)	System 2
Load fulfillment		
% of time:	100,0	100,0
% of energy:	100,0	100,0
COP		
Average COP [-]:	4,55	4,41
Energy consumption		
Pumps and fans [kWh]:	1.791	2.111
Compressor [kWh]:	4.238	4.115
Total [kWh]:	6.029	6.226
Savings		
Yearly energy savings [kWh]:	-	-197
Yearly energy savings [%]:	-	-3,3

For Bragança city, it was verified that system 1 would be the most efficient with a COP of 4.55 compared to a COP of 4.41 of system 2. Consequently, there is an annual energetic savings of 197 kWh with system 1.

Fig. 5 displays the monthly energy consumption of both systems for faro city. As for Porto city, the meaning of bars is already explained.

Table 3 represents the summary for one-year operation.

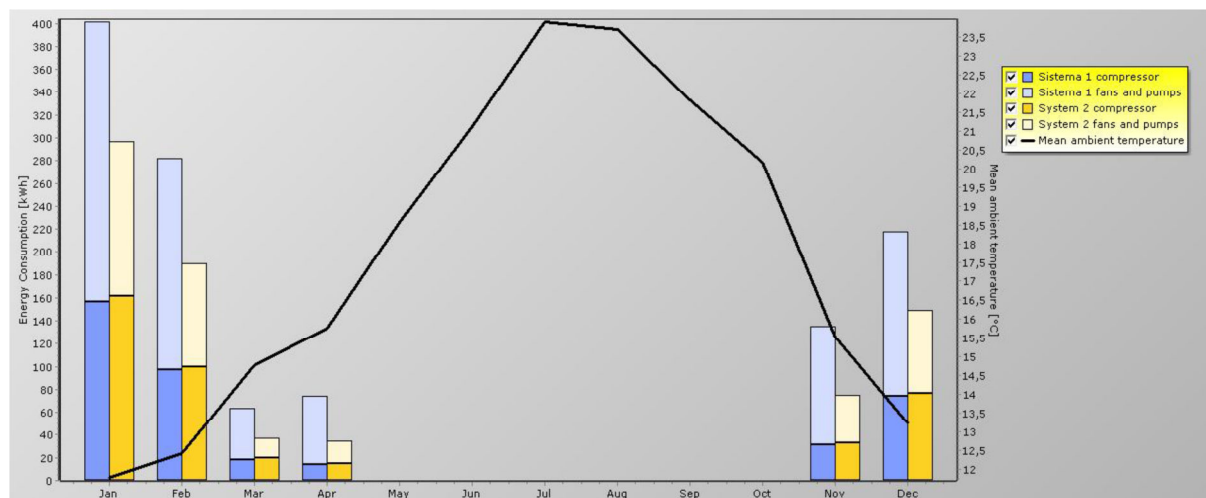


Fig. 4 - Monthly energy consumptions for the two heat pumps in Faro city.

Table 3 - Behaviour of the heat pumps in Bragança city.

	Sistema 1 (reference)	System 2
Load fulfillment		
% of time:	100,0	100,0
% of energy:	100,0	100,0
COP		
Average COP [-]:	2,45	3,67
Energy consumption		
Pumps and fans [kWh]:	780	376
Compressor [kWh]:	393	406
Total [kWh]:	1.173	782
Savings		
Yearly energy savings [kWh]:	-	391
Yearly energy savings [%]:	-	33,3

In Faro city, it was concluded that system 2 is more profitable with a COP of 3.67 higher than a COP of 2.45 of system 1. Consequently, there is an annual energetic savings of 395 kWh with system 2.

CONCLUSIONS

From the simulations it is possible to withdraw the following conclusions:

- The choice of the compressors is crucial, since only knowing their thermal capacities, we can predict the heating power that can be obtained;
- Heat pumps must be designed taking into account the local climate of the place where they will be used, as their performance is highly dependent on it;
- System 2, where the evaporation temperature was whenever possible equal to 0°C, performed better in places where the climate was warmer because it spent less energy on the fan work in the evaporator;
- System 1, where the temperature was outside temperature dependent, performed better at locations where the weather was cooler, as a result of lower evaporation temperatures, which resulted in greater energy savings in the evaporator fans

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REFERENCES

- [1]-Afonso, C. Refrigeração. Editora. FEUP. ISBN: 978-989-98632-0-0. 2012.
- [2]-Bulletin of the IIR. N° 2002-5. Sustainable Development: Achievements and Challenges in the Refrigeration Sector.
- [3]-IPU, Pack Calculation Pro. IPU. 2016.